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Solar-Electric Systems SIMPLIFIED

Scott Russell
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Perhaps what the home-scale renewable energy (RE) world needs most are ways to introduce people to RE technologies and the gizmos that make it possible. After all, even the best ideas aren't embraced until they are explained in simple terms.

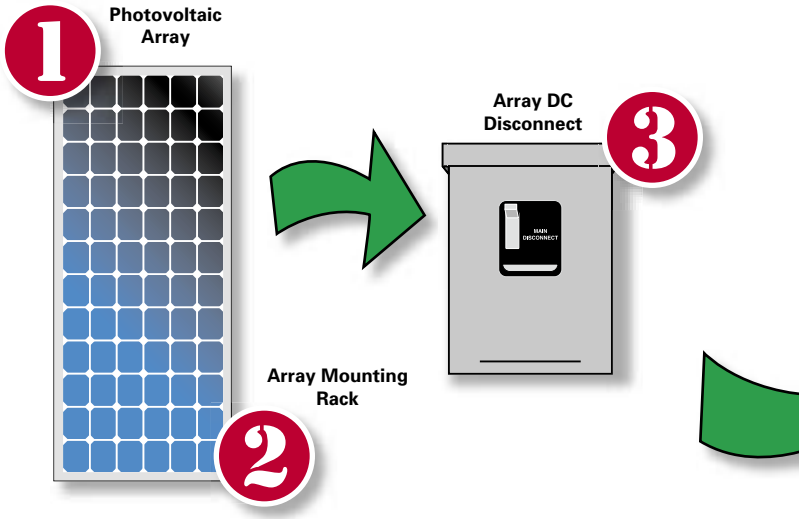
So whether *you* are the rookie who wants to understand how solar-electric systems work, or that better describes your spouse, friend, or prospective customer, this article explains the guts and bolts of the three most common options in solar-electric systems: grid-intertied, grid-intertied with battery backup, and off-grid (stand-alone).

Understanding the basic components of an RE system and how they function is not an overwhelming task. Here are some brief descriptions of the common equipment used in grid-intertied and off-grid solar-electric systems. Systems vary—not all equipment is necessary for every system type. In the diagrams, the numbers in red correspond to the components needed.

GRID-INTERTIED SOLAR-ELECTRIC SYSTEM

Also known as on-grid, grid-tied, or utility-interactive (UI), grid-intertied solar-electric systems generate solar electricity and route it to the electric utility grid, offsetting a home's or business's electrical consumption and, in some instances, even turning the electric meter backwards. Living with a grid-connected solar-electric system is no different than living with grid power, except that some or all of the electricity you use comes from the sun.

In many states, the utility credits a homeowner's account for excess solar electricity produced. This amount can then be applied to other months when the system produces less or in months when electrical consumption is greater. This arrangement is called net metering or net billing. The specific terms of net metering laws and regulations vary from state to state and utility to utility. Consult your local electricity provider or state regulatory agency for their guidelines.



1 Solar-Electric Panels

AKA: solar-electric modules, photovoltaic (PV) panels

PV panels are a solar-electric system's defining component, where sunlight is used to make direct current (DC) electricity. Behind a PV panel's shimmering facade, wafers of semiconductor material work their magic, using light (photons) to generate electricity—what's known as the *photovoltaic effect*. Other components in your system enable the electricity from your solar-electric panels to safely power your electric loads like lights, computers, and refrigerators.

PV panels are assigned a rating in watts based on the maximum power they can produce under ideal sun and temperature conditions. You can use the rated output to help determine how many panels you'll need to meet your electrical needs. Multiple modules combined together are called an array.

Although rigid panels are the most common form of solar electricity collector, PV technology also has been integrated into roofing shingles and tiles, and even peel-and-stick laminates (for metal standing-seam roofs).

PV modules are very durable and long-lasting—most carry 25-year warranties. They can withstand severe weather, including extreme heat, cold, and hail stones.

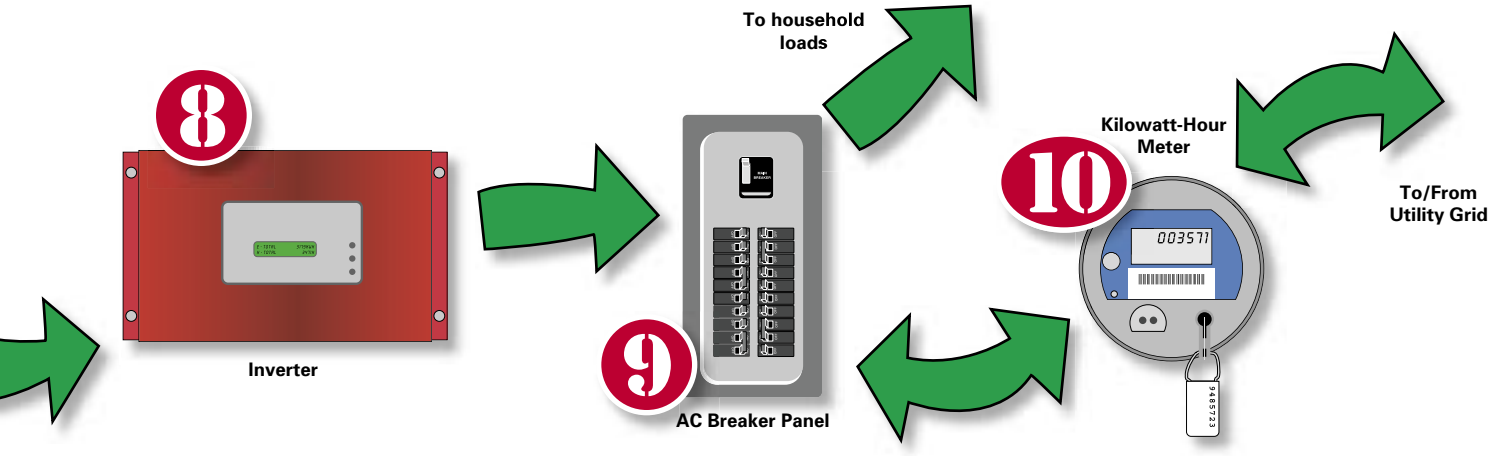
2 Array Mounting Rack *AKA: mounts, racks*

Mounting racks provide a secure platform on which to anchor your PV panels, keeping them fixed in place and oriented correctly. Panels can be mounted using one of three approaches: 1) on a rooftop; 2) atop a steel pole set in concrete; or 3) at ground level. The specific pieces, parts, and materials of your mounting device will vary considerably depending on which mounting method you choose.

Usually, arrays in urban or suburban areas are mounted on a home's south-facing roof, parallel to the roof's slope. This approach is sometimes considered most aesthetically pleasing, and may be required by local regulators or homeowner's associations. In areas with a lot of space, pole- or ground-mounted arrays are another choice.

Mounting racks may incorporate other features, such as seasonal adjustability. The sun is higher in the sky during the summer and lower in the winter. Adjustable mounting racks enable you to set the angle of your PV panels seasonally, keeping them aimed more directly at the sun. Adjusting the tilt angle increases the system's annual energy production by a few percent. The tilt of roof-mounted arrays is rarely changed—adjusting the angle is inconvenient and sometimes dangerous, due to the array's location.

Changing the tilt angle of pole- or ground-mounted arrays can be done quickly and safely. Pole-mounted PV arrays also can incorporate tracking devices that allow the array to automatically follow the sun across the sky from east to west each day. Tracked PV arrays can increase the system's daily energy output by 25 to 40 percent.



3 Array DC Disconnect

AKA: PV disconnect

The DC disconnect is used to safely interrupt the flow of electricity from the PV array. It's an essential component when system maintenance or troubleshooting is required. The disconnect enclosure houses an electrical switch rated for use in DC circuits. It also may integrate either circuit breakers or fuses, if needed.

4 Charge Controller

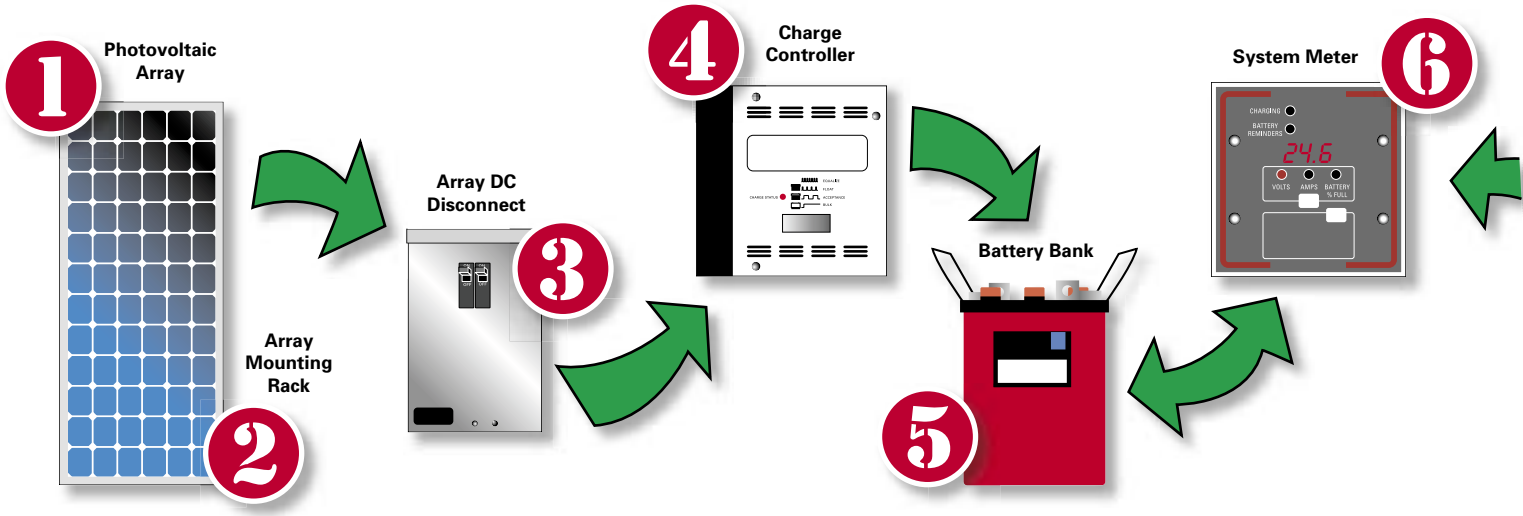
AKA: controller, regulator

A charge controller's primary function is to protect your battery bank from overcharging. It does this by monitoring the battery bank—when the bank is fully charged, the controller interrupts the flow of electricity from the PV panels. Batteries are expensive and pretty particular about how they like to be treated. To maximize their life span, you'll definitely want to avoid overcharging or undercharging them.

Most modern charge controllers incorporate maximum power point tracking (MPPT), which optimizes the PV array's output, increasing the energy it produces. Some battery-based charge controllers also include a low-voltage disconnect that prevents overdischarging, which can permanently damage the battery bank.

GRID-INTERTIED SOLAR-ELECTRIC SYSTEM WITH BATTERY BACKUP

Without a battery bank or generator backup for your grid-intertied system, when a blackout occurs, your household will be in the dark, too. To keep some or all of your electric needs (or "loads") like lights, a refrigerator, a well pump, or computer running even when utility power outages occur, many homeowners choose to install a grid-intertied system with battery backup. Incorporating batteries into the system requires more components, is more expensive, and lowers the system's overall efficiency. But for many homeowners who regularly experience utility outages or have critical electrical loads, having a backup energy source is priceless.



5 Battery Bank

AKA: storage battery

Your PV panels will produce electricity whenever the sun shines on them. If your system is off-grid, you'll need a battery bank—a group of batteries wired together—to store energy so you can have electricity at night or on cloudy days. For off-grid systems, battery banks are typically sized to keep household electricity running for one to three cloudy days. Grid-intertied systems also can include battery banks to provide emergency backup power during blackouts—perfect for keeping critical electric loads operating until grid power is restored.

Although similar to ordinary car batteries, the batteries used in solar-electric systems are specialized for the type of charging and discharging they'll need to endure. Lead-acid batteries are the most common battery used in solar-electric systems. Flooded lead-acid batteries are usually the least expensive, but require adding distilled water occasionally to replenish water lost during the normal charging process. Sealed absorbent glass mat (AGM) batteries are maintenance free and designed for grid-tied systems where the batteries are typically kept at a full state of charge. Gel-cell batteries can be a good choice to use in unheated spaces due to their freeze-resistant qualities.

6 System Meter

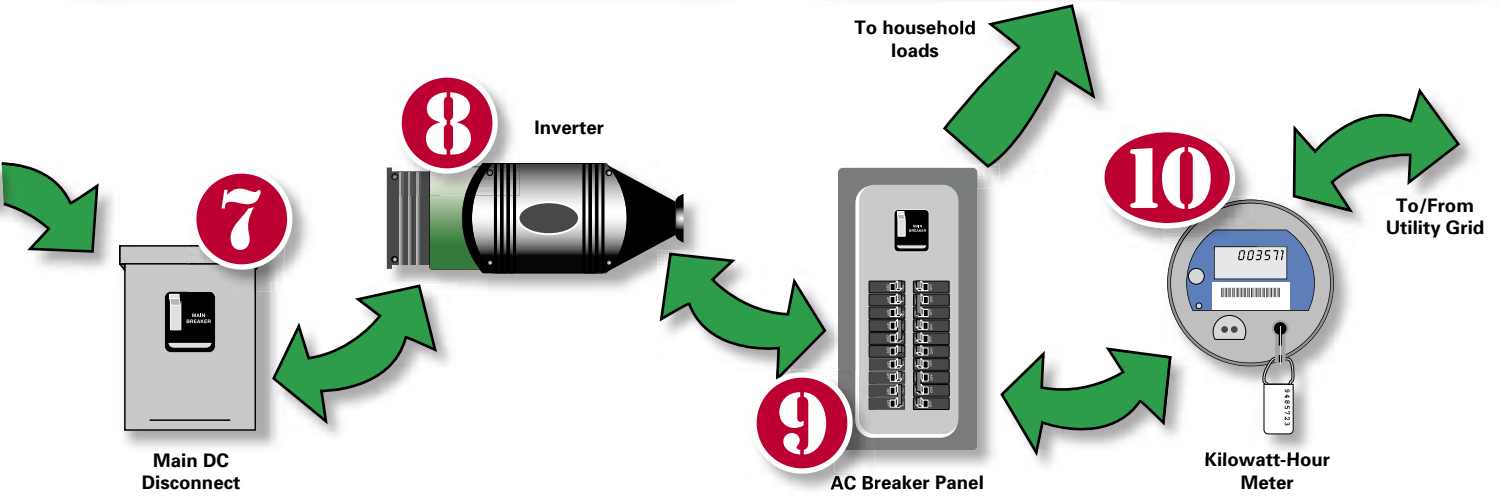
AKA: battery monitor, amp-hour meter

System meters measure and display several different aspects of your solar-electric system's performance and status, tracking how full your battery bank is; how much electricity your solar panels are producing or have produced; and how much electricity is in use. Operating your solar-electric system without metering is like running your car without any gauges—although possible to do, it's always better to know how much fuel is in the tank.

7 Main DC Disconnect

AKA: battery/inverter disconnect

In battery-based systems, a disconnect between the batteries and inverter is required. This disconnect is typically a large, DC-rated breaker mounted in a sheet-metal enclosure. This breaker allows the inverter to be quickly disconnected from the batteries for service, and protects the inverter-to-battery wiring against electrical fires.



8 Inverter

Inverters transform the DC electricity produced by your PV modules into the alternating current (AC) electricity commonly used in most homes for powering lights, appliances, and other gadgets. Grid-tied inverters synchronize the electricity they produce with the grid's "utility-grade" AC electricity, allowing the system to feed solar-made electricity to the utility grid.

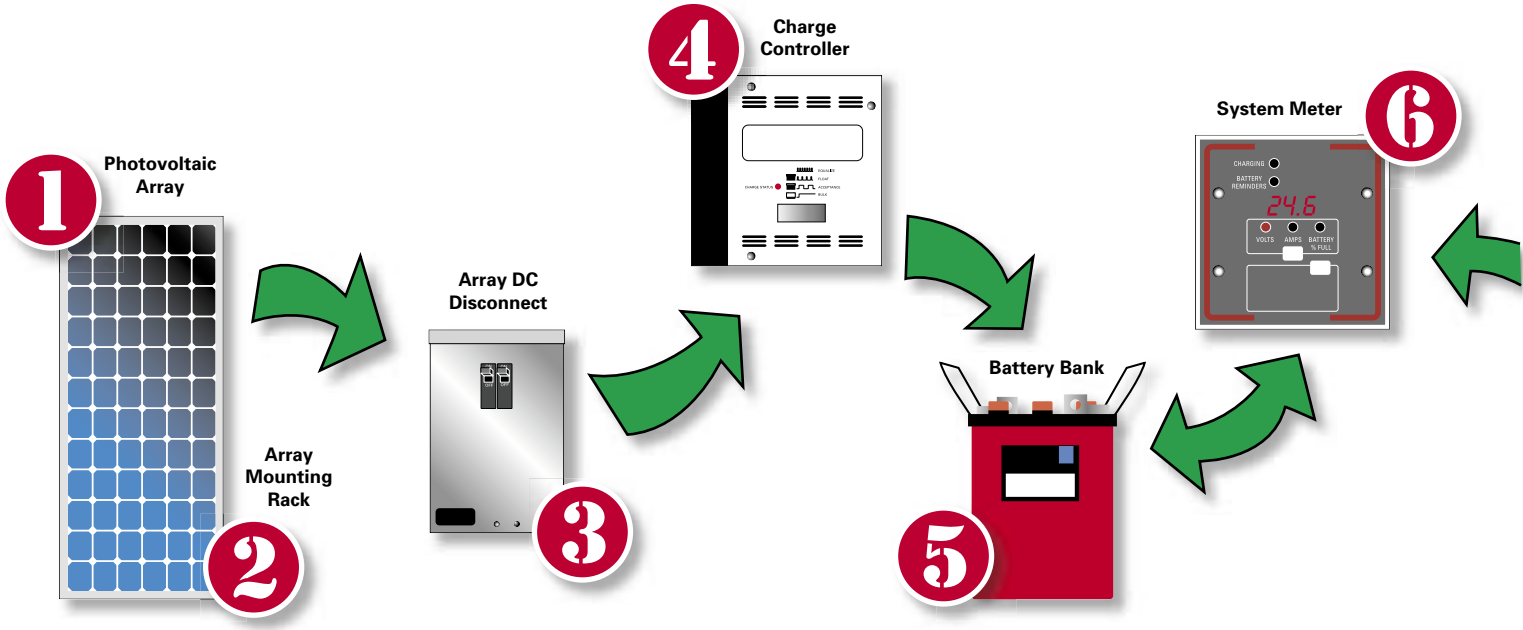
Most grid-tie inverters are designed to operate without batteries, but battery-based models also are available. Battery-based inverters for off-grid or grid-tie use often include a battery charger, which is capable of charging a battery bank from either the grid or a backup generator during cloudy weather.

Most grid-intertie inverters can be installed outdoors (ideally, in the shade). Most off-grid inverters are not weatherproof and should be mounted indoors, close to the battery bank.

OFF-GRID SOLAR-ELECTRIC SYSTEMS

Although they are most common in remote locations without utility grid service, off-grid solar-electric systems can work anywhere. These systems operate independently from the grid to provide all of a household's electricity. That means no electric bills and no blackouts—at least none caused by grid failures.

People choose to live off-grid for a variety of reasons, including the prohibitive cost of bringing utility lines to remote homesites, the appeal of an independent lifestyle, or the general reliability a solar-electric system provides. Those who choose to live off-grid often need to make adjustments to when and how they use electricity, so they can live within the limitations of the system's design. This doesn't necessarily imply doing without, but rather is a shift to a more conscientious use of electricity.



9 AC Breaker Panel & Inverter AC Disconnect

AKA: mains panel, breaker box, fuse box

The AC breaker panel is the point at which all of a home's electrical wiring meets with the "provider" of the electricity, whether that's the grid or a solar-electric system. This wall-mounted panel or box is usually installed in a utility room, basement, garage, or on the exterior of the building. It contains a number of labeled circuit breakers that route electricity to the various rooms throughout a house. These breakers allow electricity to be disconnected for servicing, and also protect the building's wiring against electrical fires.

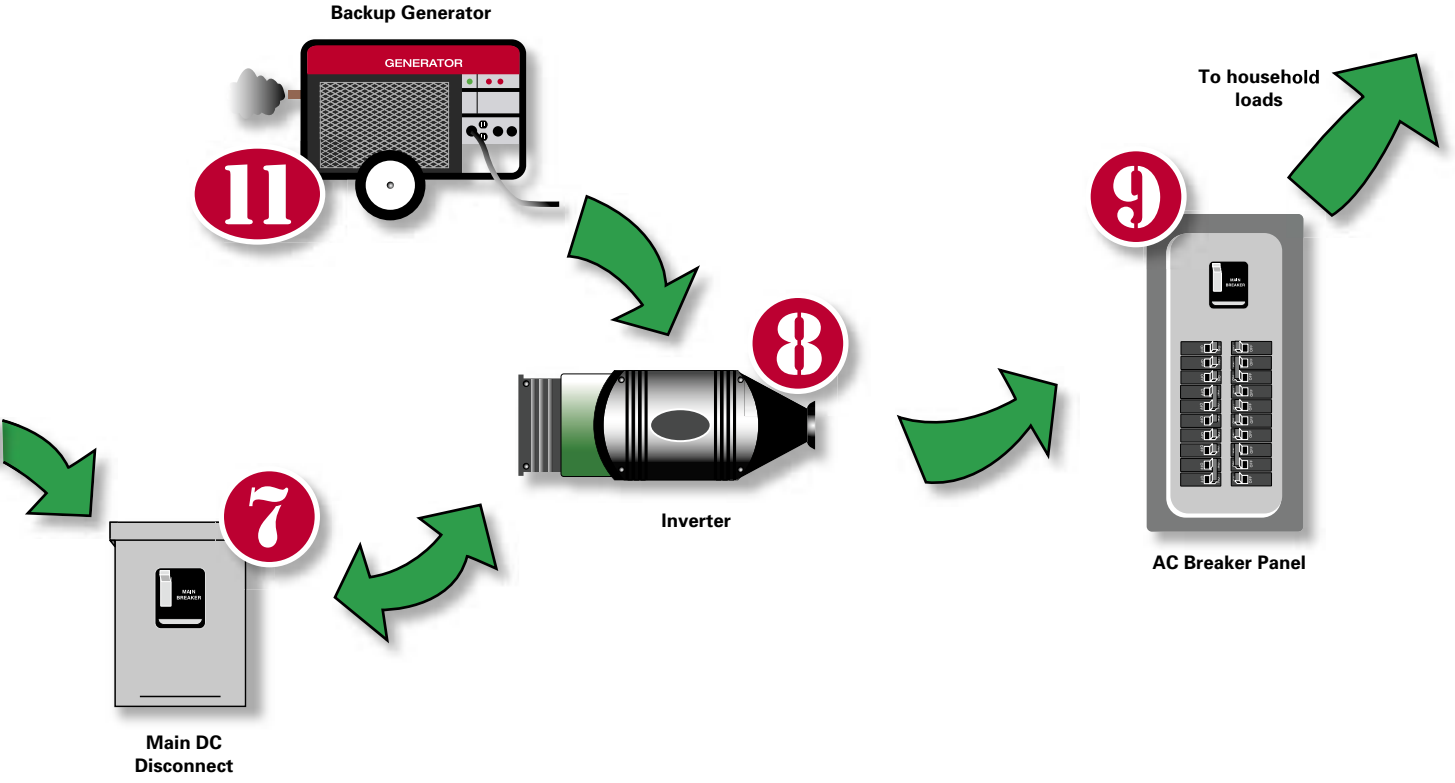
Just like the electrical circuits in your home or office, an inverter's electrical output needs to be routed through an AC circuit breaker. This breaker is usually mounted inside the building's mains panel, which enables the inverter to be disconnected from either the grid or from electrical loads if servicing is necessary, and also safeguards the circuit's electrical wiring.

Additionally, utilities usually require an AC disconnect between the inverter and the grid that is for their use. These are usually located near the utility KWH meter.

10 Kilowatt-Hour Meter

AKA: KWH meter, utility meter

Most homes with a grid-tied solar-electric system will have AC electricity both coming from and going to the electric utility grid. A bidirectional KWH meter can simultaneously keep track of how much electricity flows in each of the two directions—just the information you need to monitor how much electricity you're using *and* how much your solar-electric system is producing. The utility company often provides intertie-capable meters at no cost.



11 Backup Generator

AKA: gas guzzler

Off-grid solar-electric systems can be sized to provide electricity during cloudy periods when the sun doesn't shine. But sizing a system to cover a worst-case scenario, like several cloudy weeks during the winter, can result in a very large, expensive system that will rarely get used to its capacity. To spare your pocketbook, size the system moderately, but include a backup generator to get through those occasional sunless stretches.

Engine generators can be fueled with biodiesel, petroleum diesel, gasoline, or propane, depending on the design. These generators produce AC electricity that a battery charger (either stand-alone or incorporated into an inverter) converts to DC energy, which is stored in batteries. Like most internal combustion engines, generators tend to be loud and stinky, but a well-designed solar-electric system will require running them only 50 to 200 hours a year.

Solar-Electric Systems Demystified

As you can see, the anatomy of a photovoltaic system isn't that complicated. All of the parts have a purpose, and once you understand the individual tasks that each part performs, the whole thing makes a bit more sense. Now you're ready to look at the system articles and schematics in *Home Power* without your eyes glazing over, and you'll have a clearer understanding of what is going on in the articles.

To solidify your understanding, your next task should be to examine a solar-electric system in person. The National Tour of Solar Homes each fall is one way to see a variety of systems. Also, many renewable energy fairs and workshops feature tours of solar homes. Check the listings for your area in the *Happenings* calendar in each *Home Power* issue to find out where you can learn more about RE systems and meet the people who are using renewable energy in your area.

Access

Scott Russell • c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • scott.russell@homepower.com

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